EU Impact Monitor Project – Overview and Approach

Prajwal Shiva Prakasha[1], Patrick Ratei[1], Michel van Eenige[2], Mario Antonio Solazzo[3], Marko Alder[1], Utkarsh Gupta[4], Thierry Lefebvre[5] and Bjoern Nagel[1]

[1]German Aerospace Center (DLR), Institute of Systems Architectures in Aeronautics, Hamburg, Germany
[2]Netherlands Aerospace Centre (Royal NLR), Amsterdam, The Netherlands
[3]Italian Aerospace Research Centre (CIRA), Reliability and Safety Department Capua, Italy
[4]Cranfield University (CU), Centre for Propulsion and Thermal Power Engineering, Cranfield, United Kingdom
[5]The French Aerospace Lab (ONERA), Information Processing and Systems Department, Toulouse, France

Abstract

The EU project Impact Monitor delivers a coherent and holistic framework and toolbox that aim to become the reference choice for technology and policy assessment of the environmental-, economic- and societal-impact of European aviation R&I. Bolstered by its profound knowledge and multidisciplinary expertise, a consortium consisting of 10 research establishments and academic institutes develop this framework and toolbox by advancing credible and successfully-applied approaches beyond state of the art.

The paper shares the approach and preliminary results of the project: The collaborative framework (analysis tools/models coming from different organizations), Toolbox, dashboard and assessment results will be demonstrated for 3 use cases. Each demonstration the multilevel assessment capability considering, one or multiple levels - Aircraft, Airport and Air Transportation System level

Use Case 1 (UC1): Advanced Propulsion System; Long- and Short-Range Aircraft with Aircraft level evaluation
Use Case 2 (UC2): Continuous Descent Operations; Aircraft and Airport level assessment
Use Case 3 (UC3): Sustainable Aviation Fuel and Airt Transport System Level assessment

The sensitivity, tradeoff is demonstrated via a user-friendly Dashboard.

Keywords: Sustainable Aviation, Aircraft Design, Toolbox, System of Systems, Collaborative Assessment, Digital Engineering

1. Introduction & Objective

In the European Commission program Horizon Europe, Impact Monitor EU project [1] was funded in 2023. Impact Monitor assessment is regarded as a structured gathering and analysis of evidence of the impact of technological developments, operational advancements, sustainable aviation fuels/propulsion, or policy options to support policy-making (through science-based informed decision-making) for R&I.

In this context, the main objectives of the Impact Monitor are :

1. Develop an assessment toolbox that provides a systematic approach of the complete cycle of performing holistic environmental-, economic- and societal-impact assessments of European aviation R&I by setting out the requirements for the key steps in this cycle and providing practical, hands-on guidance and operational details;
2. Create a scalable, open-source, distributed, multidisciplinary, modular and model-independent collaborative assessment framework to support holistic environmental-, economic- and societal-impact assessments of European aviation R&I in connecting methodological, science-based and validated models and in establishing open common data interface standards;
3. Provide demonstration use-cases of the assessment toolbox and the collaborative assessment framework;

4. Establish interfaces with and reach out to key stakeholders in European aviation R&I;
5. Educate students and broader community with broader access to the assessment toolbox and the collaborative assessment framework through initiating an Impact Monitor Academy.

The ambition of Impact Monitor is to deliver a coherent and holistic toolbox and framework that jointly constitute the reference choice for technology and policy assessment of the environmental, economic and societal impact of European aviation R&I. Through this toolbox and framework, Impact Monitor subsequently supports EC in science-based informed decisions to bridge the gap between R&I, regulatory framework and economic investments as well as assist EU Member States, EC and EASA in ICAO Working Groups and other international regulatory agencies.

Impact Monitor does not start from scratch, but builds on state-of-the-art EU research outcomes and especially on the EU projects TEAM_Play[2], Clean Sky Technology Evaluator [3] and AGILE/AGILE 4.0[4].TEAM_Play created a modelling framework to connect and advance European aviation modelling capabilities to support the European perspective in the international policy arena. It dealt with environmental and economic impacts of the air transport sector by connecting models via standardised interfaces and demonstrated use cases.

Clean Sky Technology Evaluator (TE) went a step further than TEAM_Play and combined analysis models in a way to assess the Clean Sky high-level objectives, quantifying the environmental benefits of the Clean Sky concept aircraft that clustered technologies developed in the Clean Sky 1 and 2 Programmes. Clean Sky TE (starting in 2009 and still running) evolved also over time by adding additional assessment dimensions (mobility/connectivity and economic impacts), as they are crucial to obtain a holistic picture and evaluate the full impact of aviation on society.

AGILE and AGILE 4.0: AGILE (2015-2018) introduced a novel paradigm and new technologies for cross-organisational collaborative Multidisciplinary Design Analysis and Optimisation (MDAO) processes, with the main result of accelerating the setup time of MDAO development systems, reducing it by more than 40% compared to conventional MDAO approaches. AGILE 4.0 (2019-2022)[4] expanded the scope of AGILE by introducing new methodologies and implementations that leverage a Model-Based Systems Engineering (MBSE) approach in order to support the main activities of a Systems Engineering Product Development process.

While TEAM_Play had a punctual coverage of all assessment dimensions (from local to global), Clean Sky TE established a more systematic approach, where assessments are performed at three complementary levels:

1. Aircraft level, considering a single aircraft flying a mission from point A to point B – and reflecting improvements of air vehicle technologies;
2. Airport level, considering aircraft movements at and around airports, including local surrounding air-space – and reflecting the real-life impact;
3. Air Transport System level (ATS level) – reflecting the change of the aviation footprint at global fleet level.

Clean Sky Technology Evaluator is regarded as one of the most solid works to date and is thus, state of the art. Nevertheless, there is room for improvements:

Clean Sky TE did not cover all impacts. For instance, it did not address health and climate impacts, and merely touched upon economic and societal dimensions.

Clean Sky TE assessed the impact of aircraft technologies developed in the Clean Sky 1 and 2 Programmes only. Hence, not only aircraft technology developments outside of these programmes, but even all technology and policy developments in aviation outside of these programmes (such as from the SESAR/SESAR2020 and Hydrogen and Fuel Cells Programmes) were not accounted for.

Clean Sky TE focused on supporting EC and connecting a dedicated and tailored set of aviation models for assessments at aircraft, airport and ATS levels.

Clean Sky TE did not have an overarching framework integrating all three assessment levels. That is, each assessment level (aircraft, airport and ATS) had its own framework, hindering a smooth and easy exchange of relevant data between assessment levels as well as a fully integrated assessment at all levels.

Clean Sky TE's framework was not primarily set up to have an open and modular architecture with standardised interfaces. So, it is not well equipped for easily connecting alternative or future models. Clean Sky TE's toolbox was fragmented and limited: A tailored toolbox per assessment level for the environmental-impact assessments at hand. Hence, it lacked a fully systematic, coherent and consistent approach for impact-assessment at the levels simultaneously.

Further, AGILE/AGILE 4.0 only addressed aircraft level and hence, did not cover the two complementary levels (i.e. airport and ATS levels).

Impact Monitor goes beyond the state of the art by fully addressing these improvement potentials. It will establish a new European capability in form of a coherent and holistic assessment toolbox and an open collaborative assessment framework for technology and policy assessments of the environmental, economic and societal impact European aviation R&I:

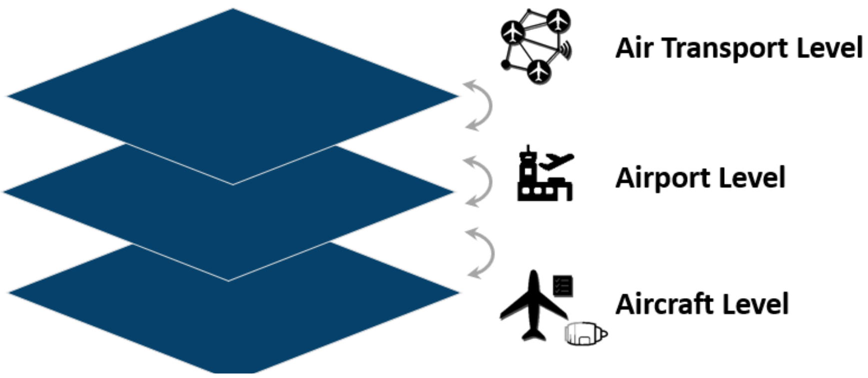


Figure 1: Multilevel System of Systems Impact Assessment Framework

Impact Monitor toolbox and framework will cover all relevant environmental, economic and societal impacts. Impact Monitor's toolbox and framework will enable impact assessments of all European relevant aviation R&I actions in Horizon Europe (such as Clean Aviation, SESAR3, Clean Hydrogen and individual Horizon Europe projects) and will not only support EC but also assist EU Member States, EASA and EEA (e.g. in ICAO Working Groups and other International regulatory agencies). In this way, Impact Monitor does not only provide direct support to EC, but also to other main stakeholders such as EU Member States, EASA, EEA, EUROCONTROL, and European aviation industry.

Impact Monitor's framework will be scalable, open-source, distributed, multidisciplinary, modular and model-independent, enabling to connect alternative or future models through open common data interface standards. Based on experiences from applications of such frameworks on aircraft design level, within Impact Monitor it will be extended towards assessment capabilities on aircraft, airport and the ATS domain.

Impact Monitor's framework is a single and coherent framework, integrating all three assessment levels and enabling a smooth assessment at multiple and interacting assessment levels simultaneously.

Impact Monitor's toolbox will provide a fully systematic approach of the complete process of performing impact assessments of European aviation R&I, ensuring alignment, coherency and consistency between the three complementary assessment levels.

2. Overall Approach

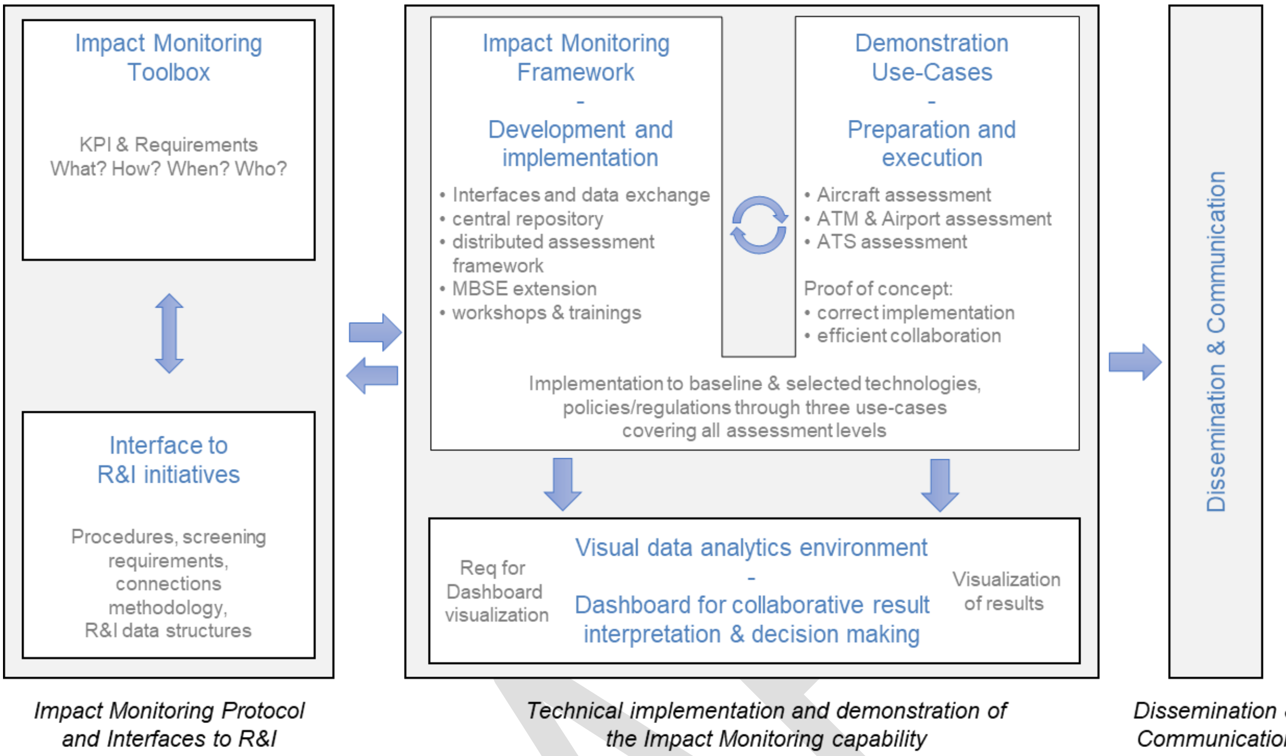


Figure 2: Overview of the pillars and their interactions within the Impact Monitoring project

Impact Monitor requires the development and application of a toolbox describing the assessment cycles as well as a model-based assessment framework, integrally covering all assessment levels defined within Clean Sky TE (see section 1.1.3). The ability of the framework to be flexibly expanded by adding assessment models on each of the levels is considered a major requirement.

Below section provides an overview of the major developments within the **Impact Monitor** project. These can be divided in three distinct pillars:

1. **Impact Monitoring Toolbox and interfaces to R&I:** In this pillar the development of the Impact Monitoring Toolbox and the establishment of connections to European R&I initiatives are covered. In the first year of the project, the focus is laid on the deduction of needs on the Impact Monitoring capability and the relevant key performance indicators to be measured. After this, the Toolbox is being developed and the connection to external R&I initiatives is established. Towards the end of the project, the Toolbox is finalized by embedding the capabilities established within the technical implementation and demonstration pillar of the project as one of the major steps within the assessment cycle. The verification and validation of its effective implementation according to the needs of all stakeholders involved (identified within the Toolbox itself and collected from external R&I initiatives) rounds-off the tasks of this part of the project.

   Within this pillar, the first project objective is to create an assessment toolbox providing a systematic approach of the complete holistic impact assessment cycle as well as the fourth objective on establishing interfaces with key stakeholders in European aviation R&I are covered.

2. **Technical implementation and demonstration of the impact monitoring capability:** the technical implementation of all components of the collaborative assessment framework, the development and technical implementation of a visual data analytics environment (Interactive Dashboard) for collaborative result interpretation and decision making as well as their application to demonstrator use cases based on the analysis capabilities available within the consortium is

grouped within this pillar. During the entire project, an intensive exchange between these the tasks ensures a well-integrated development of the analytical capabilities required for Impact Monitoring and the experiences gained will be immediately reflected in the fine-tuning and updating of the Impact Monitoring capability. Using the requirements from the Impact Monitoring Toolbox and Interfaces part of the project, until project midterm the required technologies for the Impact Monitoring Framework and the visual data analytics environment are implemented. All partners involved in the demonstrator use cases prepare their models for usage within the framework, by connecting these to central data exchange formats and extending these where necessary. Having the initial version of the framework and visual data analytics environment available, the highly iterative demonstrator and improvement phase of the project commences. During this phase, both the framework and analytics environment are continuously improved using observations from the implementation of the demonstrator use cases. At the end of this highly iterative process, all technical implementations will be coherent and available and its effective usage will be proved by the successful execution of the projects' demonstrator use cases.

By establishing a scalable, open-source, distributed, multi-disciplinary, modular and model-independent collaborative Impact Monitoring Framework and providing demonstration use-cases showing the potential of the Impact Monitoring Toolbox and Framework, the second and third project objectives are covered within this pillar.

3. **Dissemination & Communication**: this pillar covers the dissemination of the impact monitoring function, encompassing both the Impact Monitoring Toolbox, the connections to R&I initiatives and the technical framework to perform the required assessments, to the public. Furthermore, an education initiative in the form of the Impact Monitor Academy in which students can use the established Impact Monitoring Toolbox and its technical framework to perform impact assessments is planned.

   This last pillar covers the final project objective, to educate students and broader community on the developed methodology and applied technologies.

3. Toolbox

Given the wide range of European aviation R&I, the best way to perform an impact assessment varies from case to case. Nevertheless, all impact assessments must answer a set of key questions and respect a number of principles; e.g. they should be comprehensive, evidence-based, transparent and of high quality. The Impact Monitor Toolbox aims to capture these questions and principles. That is, the Impact Monitor Toolbox sets out the requirements and provides practical, hands-on guidance and operational details for the complete cycle of performing impact assessments of European R&I in aviation.

The Impact Monitor Toolbox is inspired by EC's Better Regulation **Error! Reference source not found.** and **Error! Reference source not found.** (while noting Better Regulation deals with creating legislation), but it also capitalises on work in ECAT/ANCAT-MITG and EU projects TEAM_Play [2] and Technology Evaluator in Clean Sky 1 & 2 [3]. Adopting the terminology from Better Regulation, this guidance and these operational details are denoted by 'tools'.

The complete cycle of performing impact assessments can be regarded to consist of essentially four key steps as visualised in Figure 3:

1. Assessment specification;
2. Assessment set-up;
3. Assessment execution; and
4. Assessment analysis.

To enable the specification of tools, a set of fundamentals and principles for impact assessments is to be defined, as well as a structure with the key organisational bodies involved in impact assessments.

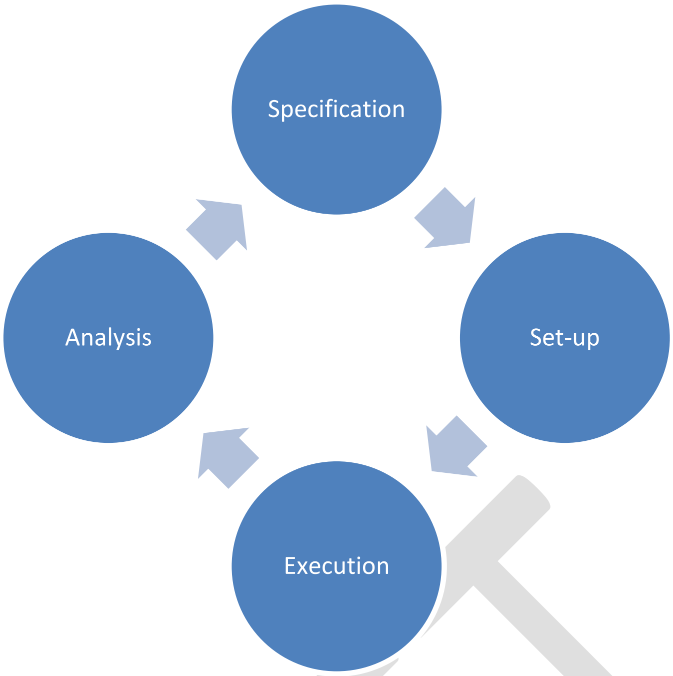


Figure 3: Impact Monitor Assessment-process Flow

The first and preliminary version of the Impact Monitor Toolbox comprises of 26 tools. In accordance with the above, these are grouped under:

- Assessment-process flow, Basics and Organisation

  Tools in this group address questions such as 'What is impact assessment?', 'What is the fundamental of impact assessment?', 'What are principles in impact assessment?', and 'What are the organisational bodies established in impact assessment?'.

- Assessment specification

  Tools in this group focus on aspects such as to properly understand the request for an impact-assessment of an aviation R&I; to specify the impact assessment of this R&I; to identify the stakeholders involved in, impacted by or served by this R&I; to identify the environmental/sustainability, economic and/or societal impacts to consider in the assessment; and to decide whether or not to accept the impact-assessment request.

- Assessment set-up

  Tools in this group relate to the preparation of performing the impact assessment specified in the previous step. Think for instance of planning the impact assessment, specifying methods and models to apply in the impact assessment, and specifying scenarios (e.g. the reference scenario against which the impacts of the R&I are assessed and the scenario with the R&I implemented).

- Assessment execution

  Tools in this group concern the actual conductance of the impact assessment. Obvious aspects are: developing required models (enhancements) and collecting data to fill any modelling and/or data gap, and applying the Impact Monitor Framework (see Section **Error! Reference source not found.**) to carry out all calculations for the impact assessment.

- Assessment analysis

  Tools in this group regard the analysis of the outcomes of the assessment execution. Typical aspects are multi-criteria, uncertainty and sensitivity analyses; interpreting the outcomes of the calculations, and the presentation and reporting of the impact assessment.

4. Framework and Dashboard

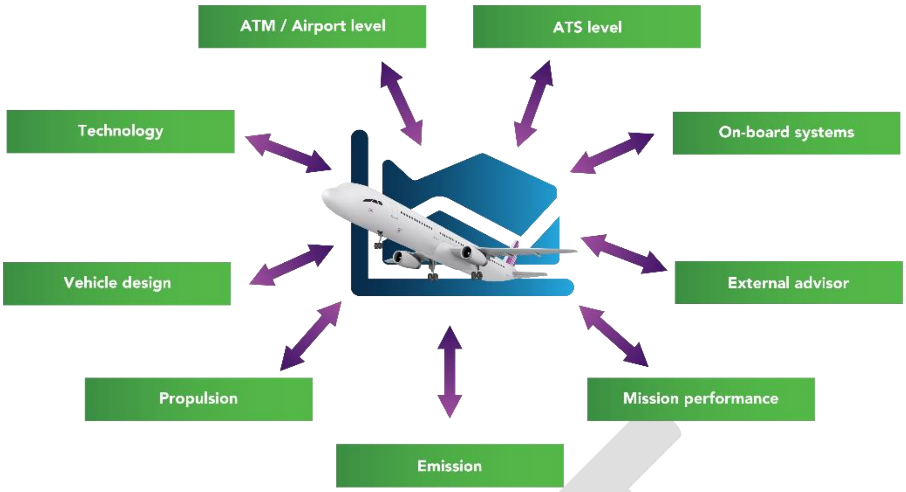


Figure 4: Collaborative approach to impact assessment

The technical implementation of the Impact Monitor Framework is based on a selection of digital enablers and processes from successful predecessor projects with a focus on collaborative engineering in aeronautics, such as the EU Horizon 2020 projects AGILE and AGILE 4.0, and DLR projects TIVA, VAMP or FrEACs. The key digital enablers in this context are:

- **CPACS**

  The Common Parametric Aircraft Configuration Schema (CPACS) [5]is a standardized data model for the air transport system. CPACS enables engineers to exchange information between their tools according to the single source of truth principle. It is therefore a driver for multi-disciplinary and multi-fidelity design in distributed environments.

- **MDAx**

  The MDO Workflow Design Accelerator (MDAx) [6] is a Multidisciplinary Design Optimization (MDO) workflow modeling environment that allows users to create, modify, and export workflows. MDAx facilitates collaborative workflow development between disciplinary experts and integrators.

- **RCE**

  The Remote Component Environment (RCE) [7] is an open source, distributed, workflow-driven integration environment. It is used to design and simulate complex systems by using and integrating custom design and simulation tools. RCE drives the workflow execution for the assessment tool chain.

Combining the key enablers outlined earlier within a collaborative setting alongside disciplinary tools is set to lay the groundwork for the Impact Monitor Framework. To guarantee the seamless integration of disciplinary tools and the efficacy of this platform, various essential criteria need to be fulfilled by the tools employed. These include maintaining consistent assumptions, handling parametric input and output quantities, offering flexibility and robustness, ensuring transparency of results, supporting batch mode operation, and delivering swift execution times. In addition, a user-friendly and informative dashboard application tailored to support decision-making processes will be developed throughout the project and linked to the Impact Monitor Framework (see Figure 5).

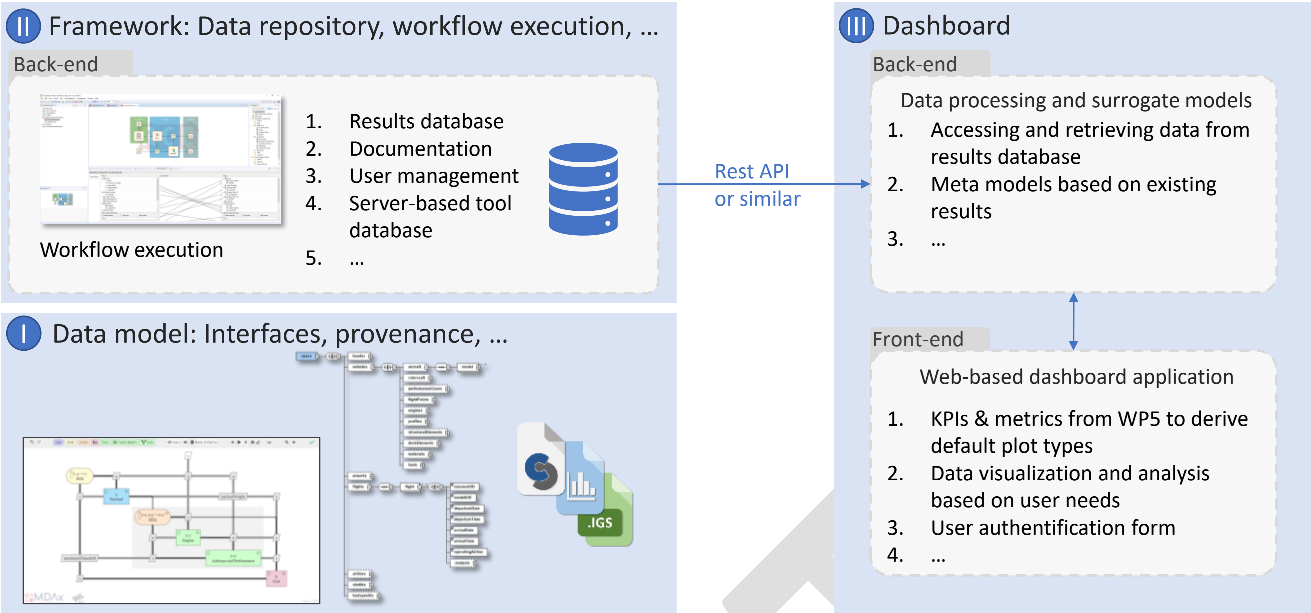


Figure 5: Draft of the planned software architecture combining data model, framework and dashboard

The Dashboard Application (DA) is being developed as an interactive web-based visual and data analytics environment for technology evaluation and impact assessments by conducting what-if trade-off studies. This web-based environment will be integrated with the overall Impact Monitor Framework and will be employed at the post-processing stage for design space exploration and use case data analysis.

An agile software development approach is being employed, i.e., embracing iterative cycles, close collaboration across the involved partners, and a continuous feedback loop to enhance adaptability and responsiveness in meeting evolving project requirements. A list of interactive visualization plots (e.g., scatter plots, constraints iso-contour plots, self-organizing maps, parallel coordinates plot, etc.) will be developed. Finally, the use cases developed for demonstration will be used to evaluate and improve the applicability and usefulness of the DA. A generic dashboard view as proposed is illustrated in Figure 5.

Figure 6: Dashboard application for impact assessment and results analysis.

DA will have other features and capabilities in different modules such as user management, data upload and display, plotting and editing of graphs, fluid dashboard with multiple plots, downloading and sharing reports/plots, multicriteria decision making tool etc. Here, Figure 6 illustrates the data upload module of the Dashboard Application, where a tree view can be seen when a CPACS file is uploaded. On click on a particular node, values and child nodes of that node can also be seen on the right section of the page.

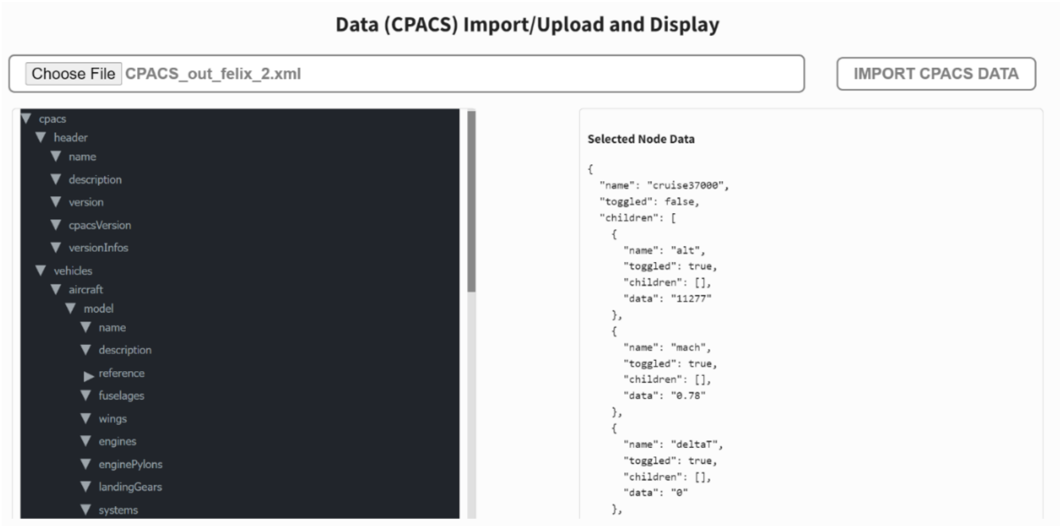


Figure 7: Dashboard Application - Data upload and display module for CPACS.

Similarly, Figure 7, illustrates the 'plot the graph' functionality and also how the plotted graph can be edited. It also displays an overlay with x-axis and y-axis parameters of the plotted graph in the background. User can change these parameters by selecting the available parameters from the dropdown and accordingly plot will change. Also, there are other functionalities like group by and add and remove filters if there is a need to filter out some data for visualizations.

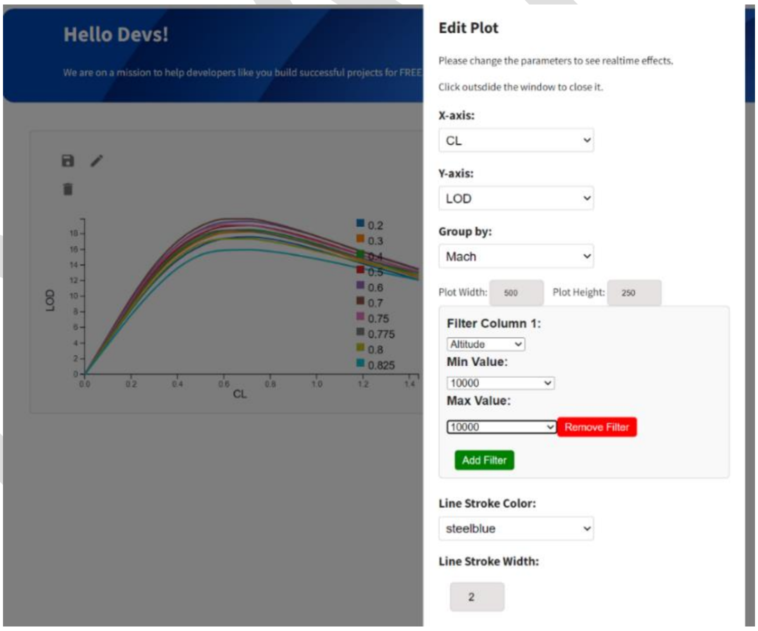


Figure 8: Dashboard Application - Plotting of new graph and editing parameters with required filters.

The DA will enable the execution of specific analyses and further allow visualization through interactive plots and charts. The user will be able to undertake trade-off studies, comparative assessments, and performance/environmental assessments for a number of aircraft concepts using the DA through web browsers.
Further demonstration along with usecase results will be made during the Conference presentation and appended to conference proceedings

5. Demonstration Use Cases

The aim of the use cases is to demonstrate the capability of the Impact Monitor framework and its dashboard application, and not to carry out detailed assessment studies (with their quantified KPIs) used for this demonstration. More specifically, every UC targets:

- An environmental-, economic- and/or societal-impact assessment of an exemplary (although hypothetical) R&I innovation in aviation;
- One or more assessment levels (i.e., aircraft, airport and/or air-transport system level);
- A dedicated subset of the requirements of the Impact Monitor framework;
- A dedicated subset of the requirements of the Impact Monitor Dashboard Application.

The implementation of the three demonstration UCs follows four steps from the definition of the scenario definition to the selection of the models, which are then integrated into collaborative workflows in order to compute and provide the desired metrics for the quantitative assessment of the defined scenario. Figure 9 illustrates the sequence of these implementation steps, which are carried out by all three demonstration UCs.

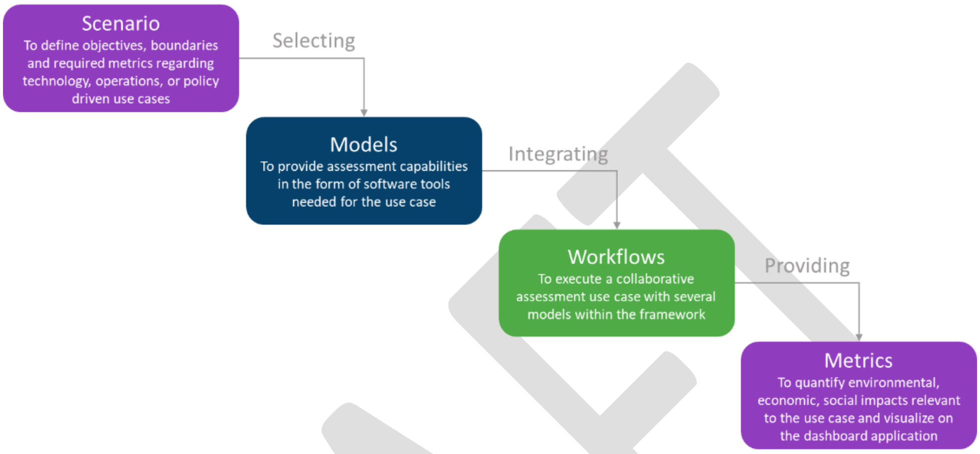


Figure 9: Implementation Steps for the Demonstration Use Cases

Jointly, the three UCs address all three assessment levels. Furthermore, these UCs intend to consider expected needs coming from selected stakeholders identified through the project's interfaces with R&I initiatives and to produce key performance indicators (KPIs) identified as part of the Impact Monitor Toolbox.

The three UCs together with their respective assessment levels are shown in Figure 10 and are titled as follows:

- UC1: Advanced Propulsion System;
- UC2: Continuous Descent Operations;
- UC3: Sustainable Aviation Fuel.

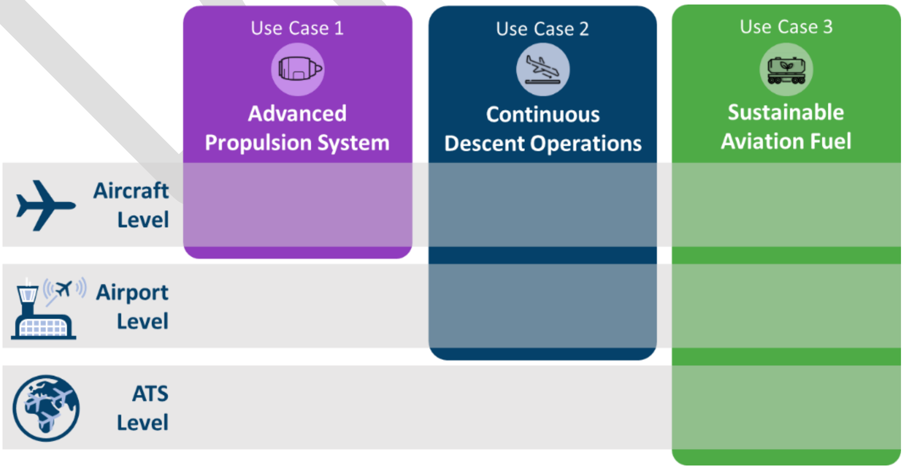


Figure 10: Schematic Representation of the Demonstration Use Cases and Assessment Levels

5.1 Use Case 1: Advanced Propulsion System

This use case targets an exemplary study of the R&I stream "Technologies on aircraft level and their impacts". It aims to investigate the viability and competitiveness of future SAF fueled long and medium range aircraft concepts with advanced propulsion systems and to demonstrate the capabilities developed by the Impact Monitor framework and interactive DA.

On a generic and high-level view, the major capabilities targeted for demonstration through UC1 can be described as:

- Targeted Impact Monitor Framework capabilities:
  - Execution of workflow;
  - Connectivity and communication of various tools provided by different partners;
  - Uninterrupted data flow among the tools.
- Targeted Dashboard Application capabilities:
  - Loading of the input data;
  - Visualisation of the results through charts, tables and maps;
  - Exporting and downloading of results.

Regarding study scenario, the use case will primarily cover aircraft-level analysis assuming a 2040/50 EIS with two different type of aircraft

  - Conventional Tube and Wing aircraft (Long Range similar to A350-900);
  - Conventional Tube and Wing aircraft (Short Range similar to A320 neo).

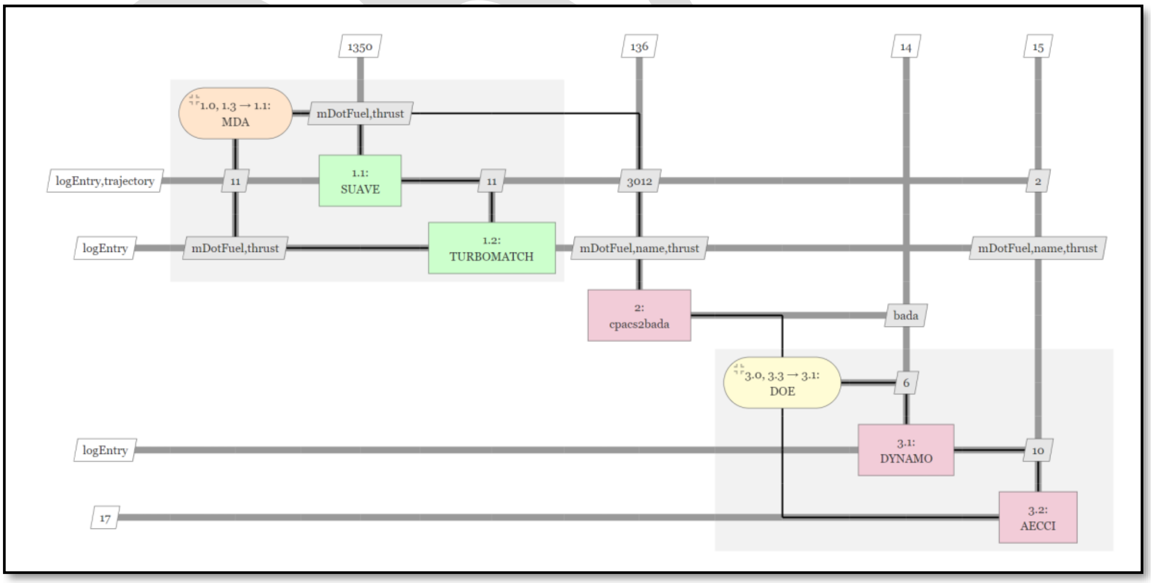
Starting with a set of pre-defined TLARs (Top Level Aircraft Requirements), the novel aircraft architecture design will be based on the above-mentioned aircraft models. To demonstrate the applicability for an aircraft family, two variants of the concept will be modelled, which will be sized for different payload / seat and range capabilities. The analysis will further entail a performance comparison for typical missions with the SAF fueled "classical technology" aircraft (adapted from Use Case 3 on SAF) to establish an improved payload-range capability & emission reduction potential. A set of metrics of interest for the evaluation of advanced propulsion systems are retained such as aircraft level fuel burn (kg), aircraft level emissions (CO_2) & energy to revenue work ratio.

The Use Case will compare the performance between two propulsion systems:

  - VHBR (9-10) – Based on Trent XWB similar (KER + SAF);
  - UHBR 15+ with Gearbox (Based on Trent Ultra fan similar) (KER + SAF).

As part of evaluating solutions and technologies for reducing the environmental impact of aviation, this use case focuses on an aircraft level assessment by analyzing several critical performance metrics related to sustainability. The key performance indicators (KPIs) agreed for assessment are fuel burn, carbon dioxide emissions (CO_2), nitrogen oxide emissions (NO_X), overall sustainability, and contrails.

In order to achieve this objective, several tools were selected and the resulting workflow is presented,



in

Figure 11.

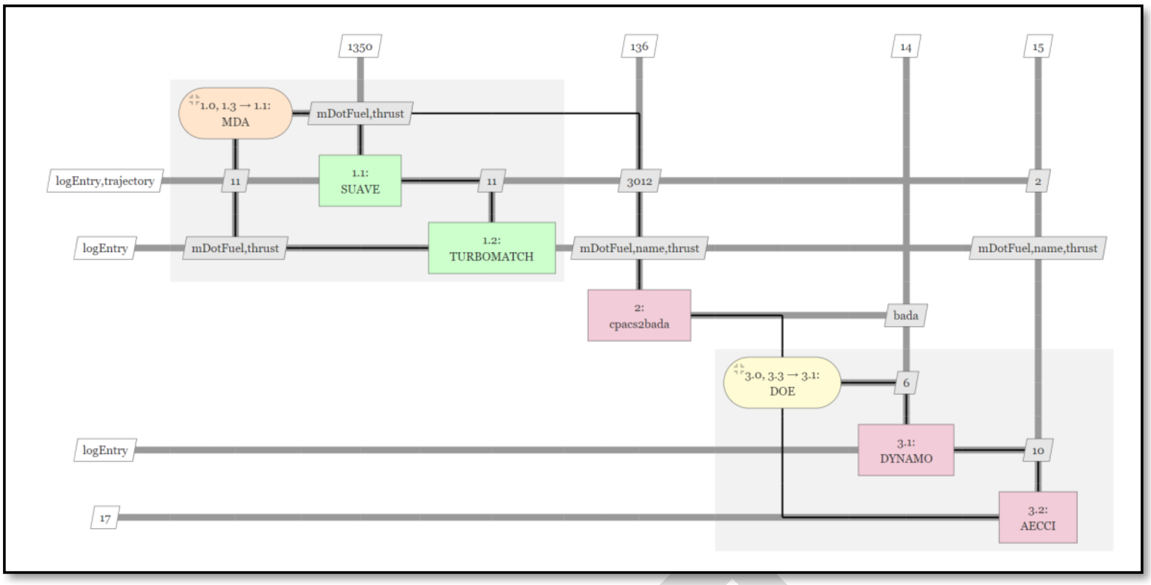


Figure 11 : A generic representation of UC1 with all the tools connected

The workflow starts with SUAVE (OAD modeling) which takes external inputs as reference aircraft model top level requirements/details and other specific inputs such as thrust, fuel mass flow, mission definition and calibration factors etc. SUAVE models and calculates the thrust requirements and pass them to TurboMatch (engine modeling) with data such as altitude, Mach number, thrust, power and atmospheric models. Turbomatch then simulates the engine and creates an engine deck for the required thrust settings at various altitudes and Mach numbers. Both tools are coupled in order to obtain a consistent engine and aircraft optimization solution. The obtained aircraft/engine couple is further passed to a Design of Experiment (DoE) loop of DYNAMO (trajectory modeling) and AECCI (emissions and contrails modeling) tools for detailed studies. Parameters such as trajectory points, time, distance, thrust, altitude, etc. are exchanged between DYNAMO and AECCI in order to provide various emission-related information for CO, CO2, NOx, SOx, HC, soot and contrails.

5.2 Use Case 2: Continuous Descent Operations

This use case targets an exemplary study of the R&I stream “Technologies, Operational or process improvements on Airport Level”. It aims to investigate the impact of Continuous Descent Operations (CDOs) through modelling and simulation at aircraft and airport level and to demonstrate the capabilities developed by the Impact Monitor framework and interactive DA.
The use case is based on the analysis of the arrival trajectories to a given airport. Increasing the demand level while keeping an affordable level of CDO approaches will enable to assess not only the effects of CDO on the capacity of the airport, but also to assess the impact in terms of fuel consumption reduction, so emissions reduction, as well as noise footprint reduction. The risk associated to the operations in the vicinity of the airport is also part of the assessment.
Regarding the study, two scenarios will be considered, one without CDO (baseline) and one with CDO. For the baseline, a scenario without CDO, and a large demand will be defined. This scenario does not need to consider maximum throughput capacity of the given airport, but a capacity close to the practical capacity, when an acceptable level of delay could be detected.
Regarding the scenarios with CDO, a set of them will be proposed to assess different levels of CDO implementation. From a low demand scenario, which should allow a larger number of CDO approaches, to a larger demand scenario, which could limit the use of the CDO strategies.
The studies will be conducted using a generic airport and the traffic scenario will be defined to fit a real airport, while using it as the baseline to define the required demand levels. Realistic weather conditions will be reproduced thanks to the use of the weather data for the simulations of the traffic around the airport and the trajectory simulations.

Considering the given definition and the global aim of the project, the objectives of UC2 are quite similar to the ones of the other use cases regarding Impact Monitor Framework capabilities and Dashboard

Application capabilities. Nevertheless, the high number of trajectories covered by the use cases and some KPIs (like noise levels) will target specific Dashboard capabilities.

Regarding implementation, Figure 12 provides an overview of the workflow involving tools from different partners. First, Scheduler tool provides a flight schedule with OD (Origin-Destination) pair, and arrival and departure time. AirTOp will then simulate the arrivals and define the specific time and queue to operate around the selected airport of the study. Therefore, the combination of Scheduler and AirTop gets the expected result associating the schedule and the trajectories each flight performs on arrival From this point, the trajectories can be treated with two paths:

- A tool chain composed of TUNA, LEAS-iT and TRIPAC will processes the 4-D trajectories from AirTOp in order to produce, respectively the noise impact (from L_{den}/L_{night}), the total emissions (e.g. CO_2, NO_X) and the individual and societal risk
- In order to increase the fidelity of the computations, DYNAMO and AECCI can compute refined 4-D trajectories including CO_2, fuel flow, and thrust along the trajectory including weather data.

The last tool, SCBA will compute the overall societal impact assessment.

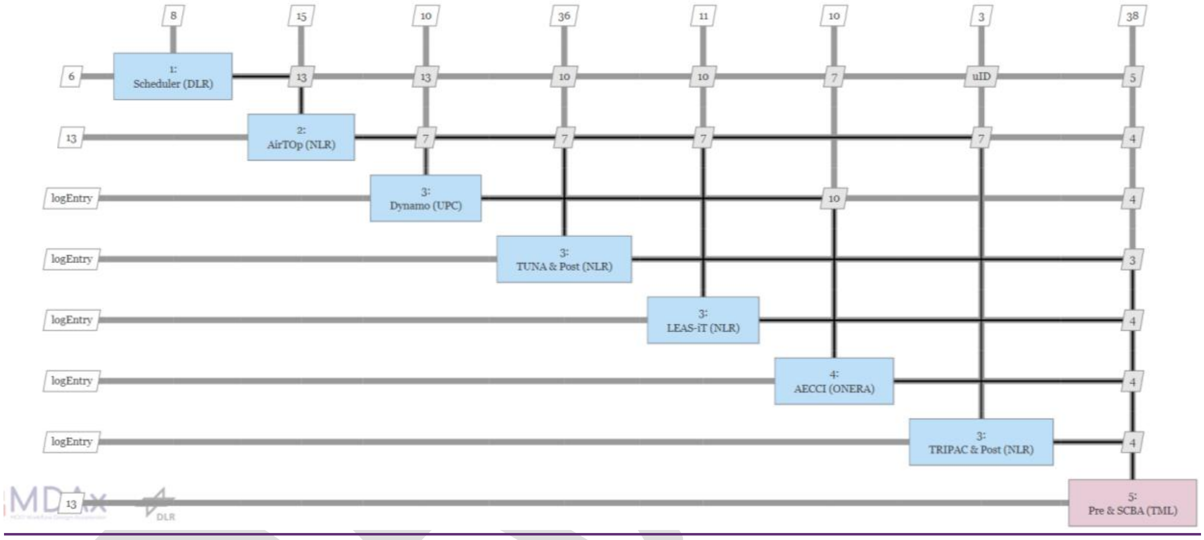


Figure 12 : A generic representation of UC2 with all the tools connected

Figure 13 provides an overview of the first stage of the workflow results obtained thanks to the coupling of Scheduler and AirTop. A visualization of the departure and arrival tracks for the scenario on reference airport is given where each flight has its own trajectory, which will fulfil the condition of performing a continuous descent as far as possible.

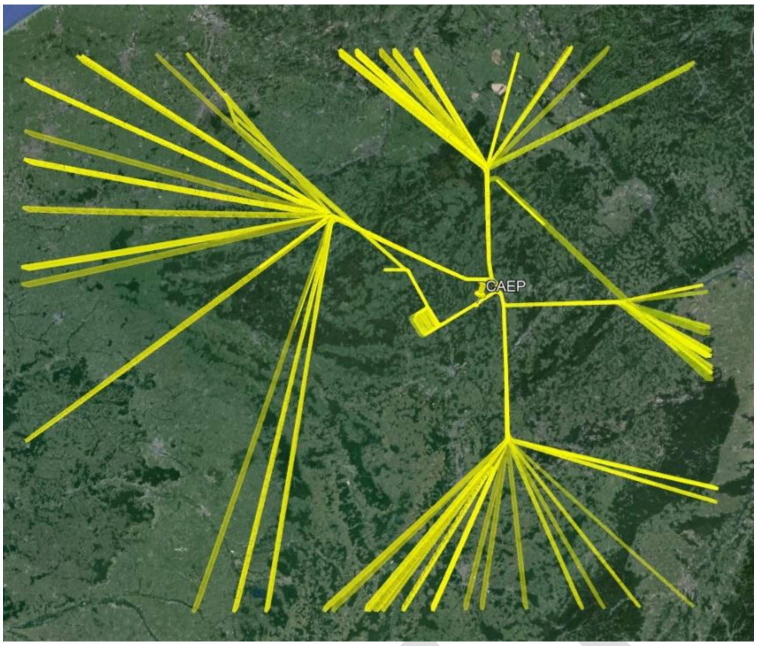


Figure 13 : Departure and arrival tracks visualization (AirTOp)

5.3 Use Case 3: Sustainable Aviation Fuel

This use case targets an exemplary study of the R&I stream “Technologies, improvements or policies and their impacts on ATS level”. It aims to investigate “Sustainable Aviation Fuel” through modelling and simulation of an impact-assessment at air-transport system level of different policies for the uptake of sustainable aviation fuels and to demonstrate the capabilities developed by the Impact Monitor framework and interactive DA.

UC3 will compare the impacts of the following two policy scenarios for promoting the uptake of SAF in aviation:

- a blending mandate (as in REFuelEU aviation)
- a carbon tax on aviation fuels.

The policy scenarios will be compared against a reference scenario without specific SAF policies. The reference scenario is based on outlooks for the economic and demographic developments, as well as existing policies (with the exclusion of SAF policies). More particularly, it will be based on an existing scenario that has been developed by DLR.
In addition, it has been decided that the time horizon of UC3 will be 2050 and that the analysis will be done for 2035 and 2050. The geographical scope consists of three broad categories of flights: (1) flights covered by the EU and UK Emission Trading System (EU ETS and UK ETS) (i.e. flights within the European Economic Area or EEA + Switzerland + UK), (2) other flights to/from these countries, and (3) other flights.
Considering the global aim of the project, the objectives of UC3 are mostly aligned with the ones of the other use cases regarding Impact Monitor Framework capabilities and Dashboard Application capabilities. Here also some specificities in terms of capabilities will be highlighted due to the geographical scope and the metrics selected (especially the economic ones).

As presented in Figure 14, the workflow is split into two stages: the calibration and the simulation stage. The aim of the calibration stage is to construct the reference scenario and to calibrate the TRAFUMA model. First, Scheduler and Emissions Tool will be used to project air travel and aviation fuel consumption and emissions in the reference scenario. This will be repeated for an alternative set of aviation fuel prices. This allows to derive the fuel demand elasticities. Based on this information the TRAFUMA model will be calibrated such that its reference scenario and demand parameters are in line with those of the other two models. By including this calibration stage, it is aimed to minimize the need for an iterative loop in the simulation stage.
In the simulation stage the effects of two SAF policy scenarios will be simulated. The effects of these scenarios will be determined compared to the reference scenario that was constructed in the calibration stage. Based on the definition of the policy scenarios, TRAFUMA will first compute the impact of these

scenarios on the user price of aviation fuel. The outcome will then be used by Scheduler to compute the impact of the change in the fuel costs on air travel. Next, TCM (Emissions Tool) will calculate the effects on aviation fuel consumption and CO2 emissions. Finally, ECOIO will compute the broader economic impacts of the SAF policies.

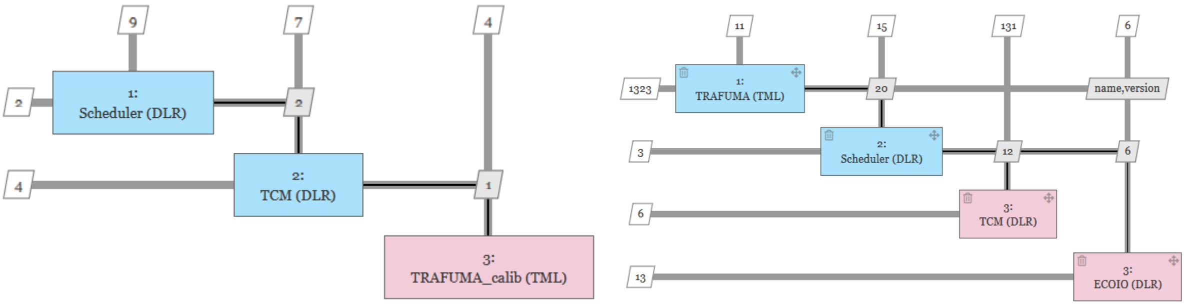


Figure 14: A generic representation of UC3 with all the tools connected (calibration and simulation step)

Figure 15 provides an overview of the result of the coupling between Scheduler and ECOIO providing the expected aviation-related employment in the EU member states in 2035. The basis for these estimates was the scheduler scenario UC3 DLRCON Y2035, which takes capacity restrictions at airports into account.

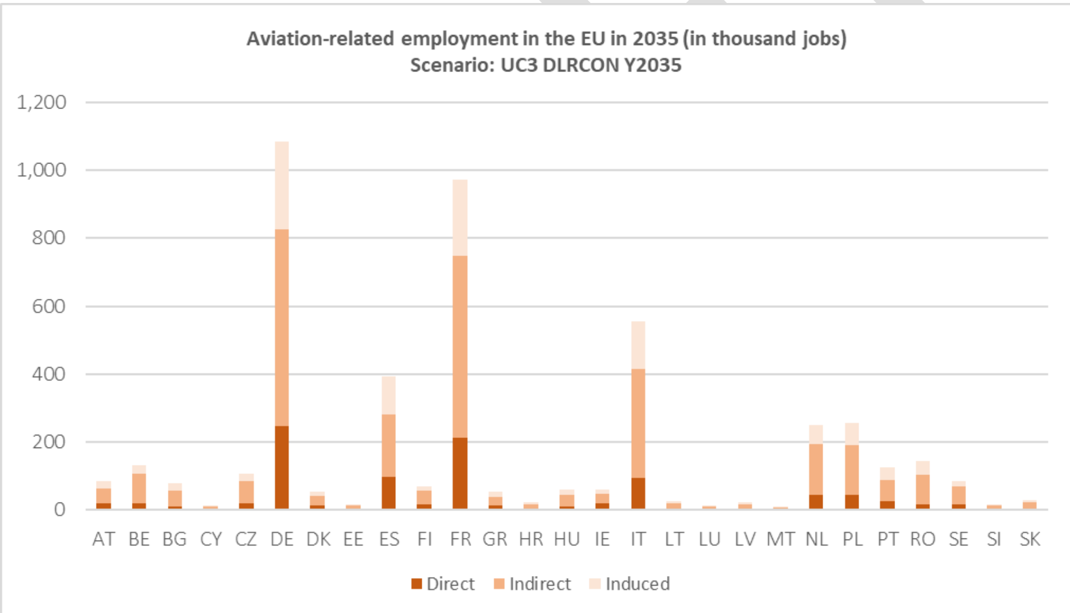


Figure 15: Example ECOIO output based on Scheduler input

6. Conclusion and Lessons learnt

The paper provides the approach for collaborative Multilevel Impact Assessment . The multilevel aspects is demonstrated by 3 use case results. The need for EU assessment is emphasized in first section of the paper and further the approach for assessment is delivered in Toolbox section, the collaborative framework was a biggest challenge to bring coherence in communication between multi domain models for assessment. Further the usecase demonstrate that the toolbox and Framework works and sensitivities visualized in Interactive Dashboard. Further results are appended in conference proceedings and made available in EU Impact Monitor Project website - Home | IMPACT MONITOR. In Future advanced models for certain domains will be included such as Noise. Climate (Co2 and NonCO2) evaluation aspects.

Contact Author Email Address

The contact author email address - mailto: Prajwal.prakasha@dlr.de

7. Funding Acknowledgement

The EU Empact Monitor project was funded by European Union under GA No 101097011. Assessing European aviation research and innovation impact, Impact Monitor | Impact Monitor | Project | Fact sheet | HORIZON | CORDIS | European Commission (europa.eu)

Views and opinions expressed are however those of the author(s) only and do not necessarily reflect those of the European Union or CINEA. Neither the European Union nor the granting authority can be held responsible for them.

8. Copyright Statement

References

[1] Assessing European aviation research and innovation impact , Impact Monitor | Impact Monitor | Project | Fact sheet | HORIZON | CORDIS | European Commission (europa.eu) extracted Jan 2024.

[2] Tool Suite for Environmental and Economic Aviation Modelling for Policy Analysis, Tool Suite for Environmental and Economic Aviation Modelling for Policy Analysis | TEAM_PLAY | Project | News & Multimedia | FP7 | CORDIS | European Commission (europa.eu) extracted jan 2024.

[3] Clean Aviation 2, Clean Sky 2 | Clean Aviation (clean-aviation.eu) extracted Jan 2024.

[4] Boggero, L., Ciampa, P. D., & Nagel, B. (2022, June 30). An MBSE Architectural Framework for the Agile Definition of Complex System Architectures. AIAA Aviation 2022, Chicago. https://doi.org/10.5281/zenodo.6800922

[5] Alder, Marko and Moerland, Erwin and Jepsen, Jonas and Nagel, Björn (2020) Recent Advances in Establishing a Common Language for Aircraft Design with CPACS. Aerospace Europe Conference 2020, 25.-28. Feb. 2020, Bordeaux, Frankreich.

[6] Bussemaker, Jasper, Luca Boggero, and Pier Davide Ciampa. "From system architecting to system design and optimization: A link between mbse and mdao." In INCOSE International Symposium, vol. 32, no. 1, pp. 343-359. 2022.

[7] Boden, Brigitte, Jan Flink, Robert Mischke, Kathrin Schaffert, Alexander Weinert, Annika Wohlan, Caslav Ilic et al. "Distributed multidisciplinary optimization and collaborative process development using RCE." In AIAA aviation 2019 forum, p. 2989. 2019.